

Applying Ontologies in Open Mobile Systems

Rodrigo Prestes, Gustavo Carvalho, Rodrigo Paes, Carlos Lucena, Markus Endler

Pontifícia Universidade Católica do Rio de Janeiro
Rua Marquês de São Vicente, 225
22453-900 Rio de Janeiro – Brasil
{rprestes, guga, rbp, lucena, endler}@inf.puc-rio.br

ABSTRACT

This position paper presents an ontology for matchmaking users' profiles in open mobile systems. This ontology can aid to promote activities involving spontaneous collaboration. This work is contextualized in an application to support the negotiation of shuttle service tickets. We also propose a matchmaking service, used to combine users' profiles to form groups to bargain discount in tickets negotiation. Furthermore, we applied a law enforcement approach to guarantee the dependability of the case study prototype implementation.

Keywords

Ontology, Matchmaking, Spontaneous Collaboration, Software Agents, Open Systems, Law Enforcement.

1. INTRODUCTION

The collaboration in a static network is different from the collaboration in a mobile one. In spite of being directed by a global goal or task, the collaboration among mobile users consists of occasional and spontaneous collaborations where users, that generally do not know each other, are interested in sharing their knowledge, ideas or developing some activities together in the context of a virtual community.

Spontaneous interaction [6] is defined as an action that occurs in a location where persons communicate with each other to satisfy immediate necessities. Naturally, this interaction occurs when two "agents" meet to negotiate, coordinate or collaborate towards a common goal.

A service to support spontaneous interaction must provide means to analyze and to discover similarities between users' profiles (matching function). With the combination of this matching service with a localization one, it is possible to discover persons with similar profiles, co-localized at the same time instant. This combination is possible due to the advances in devices like mobile phones or PDAs (Personal Digital Assistant) and to the popularization of Wireless networks (WLAN).

Ontologies are alternatives to model mobile users' profiles. An ontology is a formal description of concepts and relationships among them that exist in a domain [5]. Using ontologies, it is possible to infer and to obtain facts about users' profiles. These inferences could be useful to add new information about users' profiles. In this work, we use ontologies to represent users' profiles, describing the relationships among persons, interests and locations.

Persons have interests in places or situations where they live. Typically, specific interests have more or less importance depending on the user location. In this way, the information about

the users' profile has a specific connotation concerning which information the user wants to share with others in a specific location. Thus in a collaboration context scenario, when the information I is associated with a location L , this means that the user wants to collaborate about the interest I in the location L .

In this work, we present an ontology for users' profiles matchmaking in open mobile systems and for promoting activities involving spontaneous collaboration. We also propose a matchmaking service, used to identify users' profiles similarities.

Besides, we present a case study that was elaborated to provide means to experiment the application of this approach. This application is a shuttle service ticket negotiation system. In this application, the ontology and the matchmaking service are used to form groups that will participate in the negotiation of tickets to bargain discounts.

Complexity and uncertain are issues that must be analyzed during the development and evolution of open mobile systems. Usually, there is no control over the development of the entities that will form the system. In this way, the quality of the entities and of the whole system could be compromised. In this sense, we propose to apply a law enforcement approach guided by a risk-driven method for multi-agent systems (MAS) development. This approach aims to contribute to the improvement of dependability attributes, providing means to perform a continuous evaluation of the system guided by the identification of dependability requirements

The paper is structured as follows. In Section 2, we discuss the mobile trader case study. The ontology for mobile collaboration and the matchmaking service are presented in Section 3. Section 4 explains the law enforcement approach. Related work is described in Section 5. Finally, we conclude in Section 6.

2. MOBILE TICKET TRADER

Large airports have expressive numbers of potential users. A system with this large number of potential users and parts involved should be carefully designed and verified; otherwise it tends to be a cumbersome and presents lots of inadequate behaviors and consequences.

In an era where software permeates every aspect of our society, users could have access to the airport services using systems like PDAs and mobile phones. Due to resources limitations, the client applications must be lightweight, that is, they cannot require a large amount of memory and processor to execute ordinary tasks.

Suppose an airport where shuttle service companies and passengers have an immersive environment for negotiating shuttle tickets. Immersive in the sense that the goal of this environment is to enhance computer use by making many computers available throughout a physical environment and by making them

effectively visible to as many users as possible. Shuttle service companies and passengers are represented by software agents and they can enter or leave the environment at their own will.

Frequently, companies offer tickets in shuttle services. The goal of this kind of company is to sell the maximum number of tickets, to increase the user satisfaction and to charge them as much as possible. Passengers use palmtops when they arrive at the airport to buy shuttle tickets. Each passenger has a specific profile that defines his/her preferences concerning the destination, maximum acceptable ticket cost, and any other characteristics.

In this context, imagine a scenario where persons could bargain discounts because they are buying more tickets in a same negotiation process. This group should be formed considering common preference attributes of the participants specified in their personal interests, e.g. the same destination, price, comfort or time of departure.

In the whole negotiation process a specific step exists for forming groups of interests, where the participant personal profiles are combined aiming to inform other participants that have close interests. Using this information, it is possible to form a group with close preferences and this group can bargain discounts with the sellers.

For instance, a passenger that arrives in Rio de Janeiro Airport in a hurry wants to buy a ticket of the first shuttle going to Copacabana, i.e., he accepts to pay any price to arrive there as soon as possible. Basically, his profile can be described by the goal of minimizing the time spent with the trip, instead of a higher cost of ticket acquisition.

2.1 Development Approach

Software agents [22] can be used to develop open mobile systems. Agents were used to accomplish the scenario presented in the introduction section. The concept of an open system is considered in terms of a dynamic set of interacting entities, where no single individual or organization is in control of the construction or, consequently, behavior of the set as a whole [10]. In this sense, an open environment is uncertain; that is, the same component that provided an answer to an earlier request may not be available when called upon again [22].

Moreover, open systems consist of many distributed, asynchronous components that are open to interaction with their environment. The functionality of an open system is not defined by the result of evaluating an expression; instead, the relative state of components, the relative timing of actions, locality and distribution of the computation, among others, are all critical to the correctness of the system [1]. These systems are populated by heterogeneous components, normally developed by different people using different languages and architectures.

The explicit identification of organizational rules is an important issue in the context of open systems. With the arrival of new, previously unknown, and possibly self-interested agents, the overall organization must be able to enforce its internal coherency, despite the dynamic and untrustworthy environment [23]. Trying to regulate and to limit part of the unpredictable behavior that open systems can present, we propose to apply a law-enforcement approach [17].

Furthermore, a risk driven method is applied to identify the challenges, benefits and treats of the under development solution.

Understanding the risks, it is possible to specify interaction protocols and laws that will regulate the multi-agent system. Below (Figure 1), we have an illustration of the case study protocol specification.

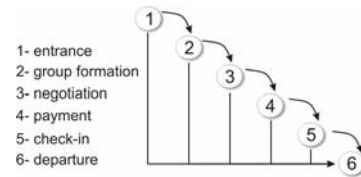


Figure 1 - Agents Execution Scenario

3. ONTOLOGY FOR MOBILE COLLABORATION

An ontology not necessarily describes all the concepts and relationships of an application domain, although, it presents a specific view point concerning some aspects of it. An ontology can also be seen as a contract between partners, in which, they agree with the relationships and concepts previously discussed, providing in this way, a communication mechanism inside a specific domain of information.

We can infer facts concerning the application domain using an ontology because it is a formal description of concepts and relationships. The information about users' profiles is generally incomplete [2], and in sometimes the users have to fill a long form of input data. Ontologies could contribute to minimize the work necessary for fulfilling this demand. For example, if a user U in a specific location where people want to buy tickets for a shuttle service, with a specific level of comfort, an application could infer that U is interested in that level too. Thus, the application could ask U to confirm the veracity of this fact in this location, explaining how it got this alternative. In this approach, the final decision is always decided by the user. In this way, we avoid that wrong inferences could interfere in users' decisions or profile maintenance, and also avoid that users could be asked to fill long preferences forms.

An ontology to support mobile collaboration must provide means to users making their relationships networks. This is one of the goals of FOAF ontology (Friend of a Friend) [8]. One of the most interesting properties of FOAF is the foaf:term_knows, i.e., a relationship that could indicate that a user know another user. We extended FOAF and included a specialization of the concept person, and then we modeled the ontology for mobile collaboration (Figure 2).

The main extension of the ontology concerns the relationships between people and interests. In spite of expressing that a person has a set of interests with an immutable importance, we decided to create a concept named InterestLevel that a user has in a specific location. Thus, an interest level refers to an interest topic and to a name of a location, for instance, "at home", "at the office", "at shopping", and etc. Locations are regions where the users usually go and where they want to define a specific preference. Examples of relationships between interests and locations could be "soccer news at home", "www at office", and so on.

After reaching a user using the matchmaking service, the ontology has some concepts that could be useful for further communication. The concept Task indicates the list of activities

that an user has available. The concept Service is specialized in sharing, indicating a directory for P2P. The concept Communication indicates which protocols could be used to send messages. There are also the concepts of language and proficiency that indicate the languages that the user can understand and the level of proficiency he has.

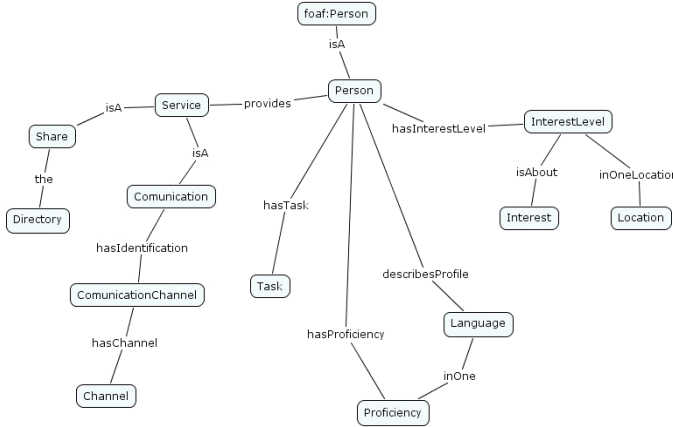


Figure 2 - Mapa conceitual da Ontologia

Using Jena [11], it is possible to manipulate, consult and persist OWL [16] files. Besides, it is possible to create inferences machines for this language. Internally, Jena has the implementation of an efficient algorithm called RETE [9]. For example, the rule (Table 1) indicates that a person is in a specific location and infers if this location is associated with a specific type of interest.

Table 1 – Jena Inference Rule Example

[rule1: (?p eg:isLocated ?l),
 (?l eg:isAssociated ?i) → (?p eg:hasInterest ?i)]

We intend to use inferences to ask confirmations to the user concerning the identified interests in a specific location.

3.1 MatchMaking Service

The MatchMaking Service is based in a linear correlation algorithm called Pearson R [18]. This algorithm is used to match the profiles. The correlation is a measure associated to the relationship between two or more variables. The variation of the correlation coefficient ranges from -1.00 till +1.00. The value -1.00 indicates a negative correlation and the value +1.00 indicates a positive one. The value 0 indicates an absent of correlation. The correlation coefficient Pearson R is calculated as indicated below, where U and J indicate the values associated to interests, \bar{U} and \bar{J} represent the average of the interests U and J.

$$r_{UJ} = \frac{\sum (U - \bar{U})(J - \bar{J})}{\sqrt{\sum (U - \bar{U})^2 \cdot \sum (J - \bar{J})^2}}$$

Figure 3 - The Pearson R Algorithm

For example, the table (Table 2) indicates the preferences of four people concerning the price and the time of departure of shuttles. The values were associated according to a scale that ranged from 1 (indicating low interest) to 10 (indicating high interest).

Table 2 - User Preferences

	Low Price	Comfort	10 AM	1 PM
John	7	7	9	3
Mary	9	6	7	9
Steve	8	5	8	4
Paul	3	8	5	7

The comparison coefficient between the interests of John and Mary is calculated as described below.

$$\text{Pearson (John, Mary)} = \frac{((7-6,5) * (9-7,75) + (7-6,5) * (6-7,75) + (9-6,5) * (7-7,75) + (3-6,5) * (9-7,75))}{\text{SQRT}(((7-6,5)^2 + (7-6,5)^2 + (9-6,5)^2 + (3-6,5)^2) * ((9-7,75)^2 + (6-7,75)^2 + (7-7,75)^2 + (9-7,75)^2))}$$

$$= -0.573964$$

3.2 MMS API

The Matchmaking Service (MMS) offers an API. Basically, this API has methods to manipulate and persist profiles descriptions, provide means to communicate with location services and has methods for realizing the comparisons between profiles 1:1, 1:N order. The data are sent by the client to the service using the OWL format. They are manipulated and are persisted using Jena. Internally, the MatchMaking Service manipulates OWL triples in relational data base tables.

The MatchMaking Service has methods that provide means to communicate it with a localization service that is associated with the *middleware* architecture called MoCA [20]. When a user U queries who is nearby has profiles similar to his, initially the localization service discovers all the MAC address of mobile devices of users that are co-localized with U. This list is returned to the MatchMaking Service and this service discovers the profiles associated with those MAC addresses. It is important to notice, that in the first time that the user uses the Matchmaking Service he sends their profile that is promptly associated with his MAC address.

After discovering from whom the addresses are, the MatchMaking Service converts the OWL triple into collections of objects and they are used by the Pearson R algorithm to calculate the correlation coefficient.

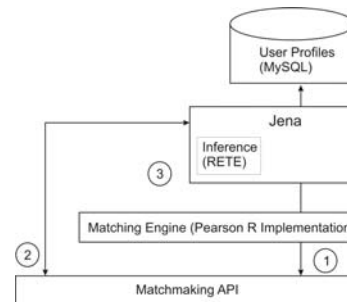


Figure 4 - MMS Architecture

The Figure 4 shows the interaction among the elements of the MMS architecture. The interaction 1 shows the request and the response to process a request, 2 shows the process when a new

user saves her /his profile. The number 3 indicates that sometimes one process infers the profiles.

4. A LAW ENFORCEMENT APPROACH

As mentioned before, the quality of open mobile system solutions could be compromised if we do not have a certain control over the development or the execution of these applications. Specification documents and rules could be elaborated to guide the development of these entities to a desired behavior, or it is possible to enforce those rules that could act like a boundary that stipulates the level of freedom that those units have to maintain considering acceptable dependability levels. This rules or laws are applied on software agents and describe permissions, prohibitions and obligations that software agents must obey [12].

In this sense, our approach provides a mechanism to enforce laws that were previously specified through all the software agents that participate in the open system. In law-enforcement architecture (Figure 5), there exists a mediator that monitors every interaction between agents and enforces the laws applying the specified consequences, whenever needed. Basically, the mediator works like an interceptor of all messages exchanged by the agents during their conversations.

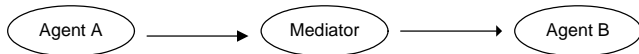


Figure 5 - Law Enforcement Architecture

An effort to obtain a more dependable solutions has a cost associated [21]. If we do not make a careful analysis of the system or the relationships that exist among their variables and neither have a criterion to guide the development decisions, the uncertain will dominate part of the resources applied during the development of the solution, i.e., development efforts could result in a waste or not achievement of quality goals.

In this work, we apply a method to prevent or reduce the likelihood of occurrence of this wastefulness guiding the law enforcement approach basing the specification, implementation and monitoring of open multi-agent system on risk analysis. The method is composed by three phases: the analysis and specification phase, the implementation phase and the law enforcement execution monitoring phase. This method is based on open systems risk identification. The risks are specified as a chain of relationships among causes and consequences states, and its probability of occurrence. Laws are elaborated and specified through the analysis of the risks. Consequences of not observing laws are described and implemented too. During the specification phase, metrics and estimations are identified. Metrics information is collected during the execution phase and is compared to the estimations. Reengineering decisions could be made based on the observation of the system resultant behavior and comparison to what was expected.

To show an example of a law description, we will further specify the payment phase. This phase starts if there is success in the end of the negotiation phase. If the negotiation process is done by a group, the whole group must complete the payment phase and honor their commitments. If one member of the group does not fulfill its obligations, there is a risk of a failure in the whole negotiation process. Then, it is necessary to specify a norm to deal with this situation and protect buyers and ticket sellers of known “bad” agents. The norm can be informally specified in the following way:

After the success of the negotiation all members of the group acquire the obligation of paying the ticket. If one of them doesn't pay the ticket, it will be prohibited of future interactions in the airport.

Furthermore, many other laws can be specified aiming to deal with the unpredictable behavior of the participant agents. This informal specification should be certainly specified in a formal manner. However, focus on the law specification is out of scope of this paper.

5. RELATED WORK

The notions of spontaneous and occasional collaboration based on profiles were presented in [13]. In this sense, they describe Proem, a mechanism that helps the publication and exchange of personal profiles. This article does not mention the use of ontology for helping the semi-automatic filling of users' profiles.

Cali et al. [2] propose the realization of inferences for completing users' profiles for other application domains. After that, they present an approach for profile matching but it is not applied on the mobile system domain.

The work presented in [3] concerns the development of applications in intelligent spaces. For this purpose, they applied techniques of semantic web to infer about information of users' contexts. Chen's work proposes an architecture for the development of intelligent spaces called CoBRA. CoBRA has some services that are similar to MoCA. But his work does not deal with spontaneous collaboration, but provides some tools that could be useful to promote the interaction between users that know each other previously.

Electronic institutions approach [19,7] formalized concepts related to law enforcement and also developed software tools to facilitate the institution's design. Law Governed Interaction (LGI) [15] proposes a mechanism for coordinate and control heterogeneous distributed systems. Cole [4] also proposes a way to identify laws in real world problems but he does not deal with issues related to law enforcement and specification. Mineau [14] proposed that laws should be specified using a conceptual graphs approach but does not propose any enforcement mechanism. These works influenced our law enforcement architecture and implementation.

6. CONCLUDING REMARKS

This position paper presented an ontology for users' profiles matchmaking in open mobile systems and for aiding in activities involving spontaneous collaboration. The ontology described in OWL has been useful to represent spontaneous collaboration data and was used as a standard for software agents' communication. As a future work, we will provide mechanisms to aid users to fill their personal profiles using inferences on the ontology. This work presented an application to aid the negotiation of shuttle service tickets in an open mobile system context. We proposed a matchmaking service, used to combine users' profiles to form groups to bargain discount in tickets negotiation.

With the application of our law enforcement approach [17], we believe that mechanisms were provided to aid the convergence of the underdevelopment software into a solution that contains the set of desirable requirements, i.e., it has behaviors that conforms to the laws descriptions. Furthermore, we believe that the domain

of open mobile systems is a good candidate to improving our law enforcement approach, because it provides complex scenarios of interaction between its participants.

7. ACKNOWLEDGMENTS

We gratefully acknowledge the financial support provided by the CNPq as part of individual grants and of the ESSMA project (552068/2002-0).

8. REFERENCES

- [1] Agha, G.A. Abstracting Interaction Patterns: A Programming Paradigm for Open Distributed Systems, In (Eds) E. Najm and J.-B. Stefani, *Formal Methods for Open Object-based Distributed Systems IFIP Transactions*, Chapman & Hall, 1997.
- [2] Cali, A.; Calvanese, D.; Colucci, S.; Noia T. D.; Donini, F. M.; A Description logic Based Approach for Matching User Profiles. In: *Proc. Of the 2004 int. Workshop on Description logics*; 2004.
- [3] Chen, H.; Perich, F.; Chakraborty, D.; Finin, T.; Joshi, A.; Intelligent Agents Meet Semantic Web in a Smart Meeting Room. In *Proceedings of the Third International Joint Conference on Autonomous Agents & Multi Agent Systems (AAMAS 2004)*, New York City, NY, July 19-23, 2004.
- [4] Cole, J. Derrick, J., Milosevic, Z., Raymond, K. Policies in an Enterprise Specification, In *Policies for Distributed Systems and Networks*, Springer-Verlag: Lecture Notes in Computer Science, v. 1995, pp.1-17, 2001.
- [5] Daum B.; Merten U.; System Architecture with XML. In: Morgan Kaufmann; 2002.
- [6] Esbjörnsson, M.; Östergren, M.; Issues of Spontaneous Collaboration and Mobility.
http://www.interactiveinstitute.se/mobility/Files/final_spont_int.pdf
- [7] Esteva, M.. Electronic Institutions: from specification to development. PhDThesis. Institut d'Investigació en Intel.ligència Artificial. 2003, Catalonia - SPAIN.
- [8] FOAF - The Friend of a Friend Project. <http://www.foaf-project.org/>
- [9] Forgy, C.L. RETE: A fast algorithm for the many pattern/many object pattern match problem, *Artificial Intelligence* 1982
- [10] Fredriksson, M., Gustavsson, R. A methodological perspective on engineering of agent societies. (Eds) A. Omicini and F. Zambonelli and R. Tolksdorf . In *Engineering societies in the agents' world*, Springer Verlag v. 2203, pp. 10-24, 2002.
- [11] Jena 2 - A Semantic Web Framework.
<http://www.hpl.hp.com/semweb/jena.htm>
- [12] Jones, A.J.I., Sergot M. "On the Characterisation of Law and Computer Systems: The Normative Systems Perspective". In Eds J.-J.Ch. Meyer and R.J. Wieringa, *Deontic Logic in Computer Science: Normative System Specification*, John Wiley and Sons, chapter 12, pp. 275-307, 1993
- [13] Kortuem, G.; Segall, Z.; Thompson, T. G. C.; Close Encounters: Supporting Mobile Collaboration through Interchange of User Profiles. In: *Proceedings First International Symposium on Handheld and Ubiquitous Computing (HUC99)*, 1999, Karlsruhe, Germany & Lecture notes in computer science; Vol 1707, ISBN 3-540-66550-1; H-W Gellersen ed, Springer, 1999.
- [14] Mineau, G.W. Representing and Enforcing Interaction Protocols in Multi-Agent Systems: an Approach Based on Conceptual Graphs, *IEEE/WIC International Conference on Intelligent Agent Technology*, 2003.
- [15] Minsky, N. H., Ungureanu, V. Law-governed interaction: a coordination and control mechanism for heterogeneous distributed systems, *ACM Press, ACM Trans. Softw. Eng. Methodol.*, v.9, n.3, 2000, pp. 273-305.
- [16] OWL Web Ontology Language Guide.
<http://www.w3.org/TR/owl-guide/>
- [17] Paes, R.B., Carvalho, G., Almeida, H.O, Lucena, C., Alencar, P.C.S. A conceptual architecture for law-governed open multi-agent systems. *ASSE 2004 - Argentine Symposium on Software Engineering*. Córdoba, Argentina. September, 2004
- [18] Resnick, et al. Grouplens: An Open Architecture for Collaborative Filtering of Netnews. *Sloan Working Paper*, February 1994.
- [19] Rodr'guez-Aguilar, J.A.. On the Design and Construction of Agent-mediated Electronic Institutions. PhDThesis. Institut d'Investigació en Intel.ligència Artificial. 2001, Catalonia - SPAIN.
- [20] Sacramento, V.; Endler, M.; Rubinsztein, H.K.; Lima, L.S.; Gonçalves, K.; Nascimento, F.N.; Bueno, G.; MoCA: A Middleware for Developing Collaborative Applications for Mobile Users, *IEEE Distributed Systems Online*, 2004 (to appear).
- [21] Sommerville, I. *Software Engineering*. 7.ed. New York: Addison-Wesley, 2004. 759p.
- [22] Sycara, K., Giampapa, J. A., Langley B. K., Paolucci, M. The RETSINA MAS, a Case Study, In (Eds) A. Garcia and et al; *Software Engineering for Large-Scale Multi-Agent Systems: Research Issues and Practical Applications*. Springer-Verlag, v. 2603, pp. 232-250, 2003.
- [23] Zambonelli, F., Jennings, N., Wooldridge, M. Developing multiagent systems: The Gaia methodology, In *ACM Trans. Softw. Eng. Methodol.*, ACM Press, v. 12, n. 3, pp. 317-370, 2003.